WSA 03:2011: Water Supply Code of Australia (Version 3.2)

Amendment No 2

Revision

Version 3.2 of the 2011 Edition WSA 03 is amended as follows:

SUMMARY This revision applies to the following elements: Clauses II, 1.2.5, 1.2.5.3, 2.10, 3.6.4, Table 3.3, Clause 3.7, Table 3.4, Clauses 3.8, 3.9, 4.1, 4..2.5, Table 4.1, Clauses 4.4.1, 4.5. 4.7, 5.5, 5.9, 5.13, 7.4. 7.6.4, 7.8, 7.9.2, 7.12,12.2, 12.3.3, 12.3.4, 12.3.5, 13.13, 15.1, 15.8, 15.22, 15,21,new Tables 15.1 and 15.2. Clause 16.6, Appendix L, new Table L1 and Appendix F5.4.

Acknowledgements:TBA

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I GLOSSARY OF TERMS

Revise and update the Reference documents as follows:

Delete definition for blue and purple

III REFERENCED DOCUMENTS

Revise and update the Reference documents as follows:

AS

AS/NZS

4441	Oriented PVC (PVC-O) pipes for pressure applications (ISO 16422:2014, MOD)	7.4.1

EN

PIPA

POP 014	Assessment of Polyethylene Welds	15.21.4.1, 15.21.5.1.1, 15.21.5.2.1.
POP 017	Material Requirements for White PE Jacket Compounds Suitable for Long Term UV Exposure	7.8.1

WSAA

Remove reference to WSA 01

WSA 01	Polyethylene Pipeline Code	4.5.2
WSA 403	Product and Material Information and Guidance – Water Supply	4.1, 4.1.1
WSA TN 08	Product Conformity Assessment Requirements	4.1

1.2.5.1 Designer needs and responsibilities

Insert new Note under 1st paragraph.

> Laws around registration of engineers are different in each state. In Australia, each state and territory is responsible for registration of engineers. Some jurisdictions don't require an engineer to be registered to practice and others have statutory regulations that require it. To ascertain the current state and territory registration requirements refer to Engineers Australia website https://www.engineersaustralia.org.au

1.2.5.3 Design outputs

Replaced item (c) with the following.

(c) Specifications for products, materials, site investigation, excavation / trench details, special construction requirements e.g. trenchless and other technical matters.

2.10 TRENCHLESS TECHNIQUES FOR PIPELAYING

Replaced item (a) (i) with the following:

(i) environmentally and/or culturally sensitive areas;

Add new Item (c) and new last paragraph

(c) when the depth of water main and/or ground conditions making trenching unsafe, risky and/or costly.

There are currently a number of trenchless technologies in the market that are suitable for the construction of boreholes and small scale tunnelling works. A general description of each technique is detailed in APPENDIX K— TRENCHLESS TECHNOLOGIES.

3.6.4 Fatigue de-rating of plastics pipes and fittings

Added new Note 3 to Table 3.3

TABLE 3.3

METHODS FOR DESIGN OF PLASTICS PIPES AND FITTINGS FOR DYNAMIC STRESSES

Pipeline system items	Guideline
Pressure pipes	PIPA Guideline POP101 : PVC pressure pipes—Design for dynamic stresses
PE pressure pipes	PIPA Guideline POP010A : Polyethylene pressure pipes—Design for dynamic stresses
PE fusion fittings	PIPA Guideline POP010B : Fusion fittings for use with polyethylene pressure pipes—Design for dynamic stresses
GRP pipes and fittings	There is limited data to detail the design of GRP pipes and fittings. The performance of GRP pressure pipes and fittings subjected to systemic fatigue is dependent on the integrity of the manufacturing process,

	particularly for fittings. Fatigue design of GRP pipes and fittings requires Water Agency authorisation with appropriate specialist input. The design must be objectively certified with reference to testing and validation of criteria documented by the manufacturer. Specification of ductile iron fittings in lieu of GRP fittings should be considered for applications subjected to significant fatigue loadings.

1. PIPA Guidelines may be downloaded from www.pipa.com.au.
2. Where fittings are required for PVC pipelines, they shall be ductile iron.
3. Only the lower de-rating factor value (Table 3.3 or Table 3.4) should be applied where pipe is de-rated for both elevated temperature and cyclic fatigue environments.

3.7 TEMPERATURE DE-RATING OF PLASTICS PIPES AND FITTINGS

Amended Table 3.4 as follows and added new Note 6 and 7

TABLE 3.4

TEMPERATURE DE-RATING FACTORS FOR PLASTICS PIPES OPERATING AT ELEVATED TEMPERATURES

Pipe material	**De-rating factor[1], t**				
	Time weighted 12 month average temperature, °C				
	20	**25**	**30**	**35**	**40**
PVC-U[5]	1.0	0.94	0.87	0.78	0.70
PVC-M[5]	1.0	0.94	0.87	0.78	0.70
PVC-O[5]	1.0	0.94	0.87	0.78	0.70
~~PE 80B[2]~~	~~1.0~~	~~1.0~~	~~0.83~~	~~0.77~~	~~0.77~~
PE 100[2,6]	1.0	0.91	0.91	0.83	0.83
GRP[4]	1.0	1.0	1.0	1.0	1.0

1. At elevated temperatures, a reduction in the design life may occur.
2. The ~~figures~~ values for ~~PE80B and~~ PE100 are based on PIPA POP013 Temperature derating of PE pipelines. The guidance provided in POP013 is based on typical PE compounds used in Australia and New Zealand to manufacture AS/NZS 4130 PE pipe and listed in ~~PIPA Guideline~~ POP004 ~~Polyethylene Pipe Compounds~~.
3. Multiply the temperature de-rating factor t by the PN number of the pipe to determine the derated PN of the pipe.
4. The figures for GRP are based on a polyester body resin. However, for continuous operation ≥35°C vinylester resins are required. No temperature de-rating is required up to 50°C for GRP pipes with vinylester body resins.
5. The ~~figures~~ values for PVC pipe de-rating are based on PIPA "Temperature Derating of PVC Pipes for Pressure Applications" (TN003) ~~and "PVC Pressure Pipes Design for Dynamic Stresses" (POP101).~~
6. Where temperature derating factors for PE fabricated fittings operating at temperatures above 20°C is required. Refer to ~~PIPA~~ POP013 for further information.
7. For PE pipes operating continuously at temperatures ≥35°C the life expectancy may be impacted – see PIPA POP013

3.8 PIPELINE COMPONENT MINIMUM PRESSURE CLASS

Added subscript Min to (PN) is first sentence as follows:

The minimum pressure class (PN_{Min}) of pipeline components shall be:

Deleted ‘components’ from the end of the second paragraph as follows:

Gravity and pumped systems comprising metallic pipes and fittings ~~components~~:

PN_{Min} ≥Design Pressure (MPa)

Deleted “reticulation” and replaced “components” with “pipes and/or fittings” in the fourth paragraph as follows:

Gravity ~~reticulation~~ systems incorporating plastics ~~components~~ pipes and/or fittings:

PN_{Min} ≥Design Pressure (MPa) x (1/t)

Modified the sixth paragraph, created new seventh and added reference to Table 3.4 as follows:

Pumped Systems exposed to ~~systematic surges and~~ incorporating plastics pipes and/or fittings ~~components~~:

The highest pressure class determined by:

PN_{Min} ≥$PN_{\text{de-rated for fatigue as per 3.6 DESIGN FOR DYNAMIC STRESSES}}$ and

PN_{Min} ≥Design Pressure (MPa) X (1/t)

where t = temperature de-rating factor for plastics components in Table 3.4

Added new paragraph to the end of Clause 3.8

Normal temperature de-rating principles should apply when determining the minimum pressure class of plastics pipe and fittings in pumped systems. Fatigue should then be considered separately, and the highest-pressure class selected. That is in the case of pumped systems the de-rating factors for temperature and fatigue are not cumulative - select the highest class arrived via Static design including temperature derating; or Dynamic design as defined in 3.6 DESIGN FOR DYNAMIC STRESSES.

Added new Note 4 and 5

NOTES

1. Plastics-bodied fittings and valves present a special problem. The geometry of these items can result in complex stress patterns that 'amplify' the apparent stress cycle. An apparently harmless pressure cycle can thus produce a damaging stress cycle leading to a shortened fatigue life. This is particularly important in the case of branch fittings such as tees. In addition, the situation can be aggravated further by the existence of stresses from other sources, for example, bending stresses induced by flexing under hydraulic thrust in improperly supported systems.
2. The design of plastics-bodied fittings and valves is not standardised. The manufacturer should be consulted for re-rating factors for cyclic loading conditions, and, irrespective of manufacturer's advice, shall be not less than the values given in PIPA guideline documents referenced in Table 3.3.

3. The pressure range is defined as the maximum pressure minus the minimum pressure, including all transients, experienced by the system during normal operations. The effect of accidental conditions such as power failure may be excluded.
4. For pressure de-rating of Polyethylene (PE) fabricated fittings, for use with polyethylene pipe made to AS/NZS 4130, apply the fitting geometry and fusion method factors in accordance with AS/NZS 4129. Where fitting geometry is not covered by AS/NZS 4129, conform to PIPA Guideline POP 006.
5. For polyethylene piping materials and systems designed to transport disinfected water ≥ 20°C and residual chlorine ≥ 0.6mg/L, the combination of higher temperature and high chlorine concentrations may result in accelerated aging of the material, potentially leading to premature brittle failure. Where water quality and average water temperature information is available, pressure class selection for polyethylene piping materials may be determined in accordance with PIPA POP018 – Polyethylene drinking water pipes in contact with chlorine and chloramine Disinfectants.

Insert new Clause 3.9 PE FABRICATED FITTINGS FOR PRESSURE APPLICATIONS DE-RATING REQUIREMENTS

3.9 PE FABRICATED FITTINGS FOR PRESSURE APPLICATIONS DE-RATING REQUIREMENTS

Polyethylene (PE) fabricated fittings, for use with polyethylene pipe made to AS/NZS 4130, shall be de-rated by the manufacturer applying the fitting geometry factor and fusion method factor, in accordance with AS/NZS 4129. Where fitting geometry is not covered by AS/NZS 4129, conform to PIPA Guideline POP 006.

De-rating the nominal pressure class is required where PE pipe or fittings will be subjected to cyclic pressures or where temperatures exceed 20°C. (Refer Clauses 3.6 and Clause 3.7)

4.1 General

Replaced the last three paragraphs with the following:

Product Specifications are listed on the WSAA website and have been published in an eBook format. Individual links to Product Specifications are provided within this Code to enhance user experience.

Note: For links to Product Specifications within this Code to work correctly, Users will need to have checked out the Product Specifications eBook from the WSAA Shop.

Each Product Specification nominates default quality assurance requirements for the product. Refer to WSA TN 08 Product Conformity Assessment Requirements and WSA 403 Part 2

Note: This Technical Note (WSA TN-08) sets out product conformity assessment requirements to supplement the conformity testing and assessment requirements of the product Standard(s) called up in a duly nominated (e.g. WSAA) Product Specification. WSA TN 08 is available from the WSAA Shop.

Additional specifications may at times be added and existing specifications may at times be changed. Water Agencies may have additional, fewer or modified specifications listed on their websites that take precedence.

Where product specifications are not available, arrangements should be made to develop and publish such documents to address essential product attributes.

When in doubt, specialist advice should be obtained, including from the pipe manufacturer.

All products and materials used in contact with drinking and non-drinking water shall comply with AS/NZS 4020.

4.1.1 Selection Guide for Pipeline Systems

Insert a new heading 4.1.1. after the last paragraph 4.1.1 Selection Guide for Pipeline Systems

The WSAA Product and Material Information and Guidance materials (WSA 403) Part 1 contain information on the principal pipeline system attributes and some details of ancillary products used in the construction of water supply networks and referenced in this Code. It outlines aspects such as product specifications, product descriptions and classifications, joint types, water industry experience and recommendations on use.

WSA 403 Part 2 provides information on the applicability and limitations of the various quality assurance options.

It does not provide instructions on life expectancy for pipeline systems as this is dependent upon design, manufacture, transport, handling, installation, operation, protection from third party damage and other external factors.

WSAA Product and Material Information and Guidance materials (WSA 403) has been published in an eBook format. A PDF copy of the WSA 403 can be downloaded directly from this eBook. Individual links to WSA 403 are provided within this Code to enhance user experience.

Please note that in order for the link to Product and Material Information and Guidance materials (WSA 403) to function properly within this Code, Users must have purchased and checked out the WSA 403 eBook from the WSAA Shop.

4.4 Product Specifications

Relevant Product Specifications include:

Included WSA PS 201

WSA PS – 201 DUCTILE IRON FITTINGS (CIOD) FOR PRESSURE AND NON-PRESSURE APPLICATIONS - DRINKING WATER, NON-DRINKING WATER SUPPLY AND SEWERAGE

Amended title of WSA PS – 212 as follows:

See WSA PS – 212 (Replaced by WSA PS – 201)

4.2.5 Property services – non-drinking water

Updated the 2nd row of Table 4.1 replaced comma (,) with (or)

TABLE 4 1

COLOUR DIFFERENTIATION OF DRINKING WATER AND ON-DRINKING WATER COMPONENTS IN DUAL WATER RETICULATION SYSTEMS

COMPONENT		DRINKING WATER SYSTEM	NON-DRINKING WATER SYSTEM
RETICULATION MAINS			
Pipe	PVC	Light blue	Purple
	PE	Blue or black with blue stripes or jackets	Black with purple stripes or jackets
	Ductile Iron	Blue PE sleeving or blue coating[2,6]	Purple PE sleeving or purple coating[2,6]

4.5.2 Sizes and configurations

Removed reference to ‘PE80and PE100’ in the first sentence of Clause 4.5.2.

Amended Clause 4.5.2 (a) as follows:

(a) Where tapping is specified for PE mains use either:

(i) an authorised electrofusion tapping saddle complying with WSA PS–329 or

(ii) an authorised mechanical tapping saddle complying with WSA PS–310.

Amended Clause 4.5.2 (c) as follows:

(c) Jointing of PE mains shall be specified in accordance with 15.21 WELDING OF PE PIPES

4.7 GRP Pipeline System

4.7.1 Product Specifications

Insert new Product Specification

WSA PS – 219 GLASS REINFORCED PLASTICS (GRP) PIPES AND FITTINGS FOR PRESSURE AND NON-PRESSURE APPLICATIONS - DRINKING WATER, NON-DRINKING WATER SUPPLY AND SEWERAGE

5.5 TRENCHLESS TECHNOLOGY

Deleted the last paragraph and updated the references as follows:

The Australasian Society Trenchless Technology has developed the following Trenchless Guidelines, Standards and Specifications to assist industry users in Australia and New Zealand in utilising these technologies. For further information refer to:

ASTT Guidelines on

HDD, Pipe Bursting and Microtunnelling;

Microtunnelling Design Guidelines Sewer (MDG-S)

ASTT Standards for

Horizontal Directional Drilling;

Pipe Bursting;

Microtunnelling and Pipe Jacking

ASTT Sample Specification for

Horizontal Directional Drilling;

Pipe Bursting;

Microtunnelling and Pipe Jacking;

Microtunnelling and Pipe Jacking;

Design of Structural Pipe Lining

ASTM F1962.

5.9 Connection of New Mains to Existing Mains

5.9.1 Product Specifications

Include new Product Specification

WSA PS – 288 TAPPING FERRULES - PRESSURE APPLICATIONS FOR DRINKING WATER AND NON-DRINKING WATER SUPPLY

5.13 DISUSED OR REDUNDANT PIPELINES

Inserted new 4th, 5th and 6th paragraph in new Note between paragraph 5 and 6.

> All works on disused or redundant items in road reserves shall comply with the road authority's requirements.
>
> All works on disused or redundant in railway reserves shall comply with the railway authority's requirements.

Leaving any asbestos waste underground, including sectioned, broken or fragmented AC pipe as a result of AC pipe replacement, removal or rehabilitation may be a contravention of environmental protection law and occupational health and safety laws.

> Removal of AC sewers shall be done in accordance with all relevant legislation and regulations.

Inserted new last paragraph as follows:

> The works undertaken on disused or redundant items shall be recorded as part of the Work As Constructed details.

7.4 EXTERNAL FORCES

7.4.1 General

Deleted 4th paragraph and replaced with the following Note: as follows

AS/NZS 4441:2008 stated

"In order to take full advantage of the economics and performance of PVC-O pipes, it is essential that application designers are cognisant of the limitations of thin-walled pipes and information is presented in this Standard on lateral stiffness, negative pressure resistance and aspects of joint performance. Users should refer to AS/NZS 2566 for further advice."

Insert new Clause 7.6.4 Encased PE pipelines

> 7.6.4 Encased PE pipelines
>
> *When grouting or encasing PE pipes, it is important to determine the maximum hydrostatic grouting pressure and the maximum temperatures that may be generated due to the exothermic reaction caused by the concrete curing. This will assist with determining if the MAOP selected of the encased PE pipe will be sufficient to prevent the pipe from deflecting or buckling. If you have concerns about the grouting pressure, you can carry out the grouting process with the pipe being internally pressurised.*

Where PE pipes are to be encased in concrete precautions shall be taken to protect the pipe surface from damage that could occur as a result of because of differential movement of the encased pipe.

Protection may be by wrapping in a compressible membrane with a minimum of 2-3 mm made polyethylene, PVC , geotextile fabric or felt.

NOTE: Encasement in concrete may compromise the inherent flexibility of a PE pipeline and should only be used in special circumstances. In unstable ground conditions, the use of geotextile to form a ground beam (as shown in AS/NZS 2566.2) may provide a superior solution.

7.8 Above-Ground Water Mains

After the second paragraph, the following two paragraphs were inserted.

Where a section of main is to be supported by a bridge, the bridge designer shall be consulted to determine expected bridge movements and deflections due to dead/live load, braking forces, temperature etc. Where necessary, the water main shall be provided with sufficient articulation to accommodate such movements and deflections.

Due to ongoing operation and maintenance issues, aboveground water mains in lieu of buried water mains are generally not preferred. Alternative options shall be considered in consultation with the Water Agency prior to adoption of an aboveground installation.

Inserted new Clause 7.8.1

7.8.1 PE Above-Ground Installation

Where approved by the Water Agency, PE pipes may be installed above ground for pressure applications in both direct exposure and protected conditions.

The design shall consider increased temperature and measures to mitigate elevated pipe temperature.

PE Pipe shall be extruded from black compound or black compound with a fully coextruded white jacket. White jacketing compounds shall conform to PIPA Guideline POP 017. Compounds evaluated against these requirements are listed in PIPA Guideline POP 004. Pipe fittings shall share an equivalent level of protection as the parent pipe.

Polyethylene pipe for above-ground applications shall be either continuously supported (preferred) or with support spacings which comply with the requirements in AS/NZS 2033.

The location and type of support selected must take into account provision for thermal movement. If the supports are to resist thermal movement, an assessment of the stress induced in pipes, fittings and supports may need to be made.

7.9.2 THRUST BLOCKS

7.9.2.1 GENERAL

Insert new clause and Note after the first paragraph.

> *PE Electrofusion joints, butt weld joints and compression fittings that comply with AS/NZS 4129 can develop the full axial strength of the pipe and in buried applications do not require thrust blocks to resist internal pressure forces at bends, tees, reducers, offsets, dead ends, etc.*

Because of the general absence of anchor blocks in PE pipe systems, caution should be exercised when specifying the use of non-end thrust resistant fittings such as wrap-around stainless steel flanged off-take clamps for post installation works.

7.12 Installation Treatments for Water Mains

References to RRJ steel or DI or PVC for GRP mains in Table 7.6 need to be revised as follows:

> Table 7.6 MINIMUM INSTALLATION TREATMENTS FOR WATER MAINS
>
> 2nd-row third column
>
> Reinforced concrete encasement of DI, PVC or GRP main utilising elastomeric push-in joints
>
> 3rd-row third column
>
> Fully welded or steel main utilising elastomeric push-in joints in stabilised sand embedment
>
> DI main utilising elastomeric push-in joints in stabilised sand embedment
>
> 4th-row third column
>
> PVC or GRP main utilising elastomeric push-in joints in stabilised sand embedment
>
> 5th -row third column
>
> DI, PVC or GRP main utilising elastomeric push-in joints in sand embedment

9.2.5 Pipeline system acronyms

Replace the term ‘rubber ring’ with an ‘elastomeric seal’

12.2 DELIVERY INSPECTION OF PRODUCTS AND MATERIALS

Replaced item (e) with the following

(e) Electrofusion PE fittings not sealed in original bags or cartons or with damaged sealed bags or cartons.

Inserted new last paragraph.

Do not use any rejected products or materials in the Works.

12.3.3 Unloading and handling

Replaced the first paragraph with the following:

Ensure personnel involved in unloading and handling wear appropriate personal protection equipment.

Replaced the second paragraph with the following:

Prevent damage to products during unloading and handling by

12.3.4 On-site storage

Insert new third paragraph.

Keep the ends of plastics pipe and fittings or couplings on GRP pipe free of loading.

In the tenth paragraph replace the term ‘rubber ring’ with an ‘elastomeric seal’ as follows:

Store elastomeric seals, lip seals and gaskets away from sunlight and in an unstrained condition.

Add the following new sentences after the tenth paragraph.

Electrofusion fittings shall be stored in their original packaging.

Joint lubricants shall be stored in sealed containers until ready for use.

Insert new clause

12.3.5 Coiled plastics pipe

Coils of pipe may be heavy and it must be remembered the coil is under tension . The amount of energy stored in the coil will depend on the size of pipe, the class of the pipe, and the size of the coil. The amount of energy can be substantial and cause significant injury, death or damage if released in an uncontrolled manner.

Coiled plastics pipe when removed from the coil or drum may be oval and curved. The extent of ovality and curvature will depend upon the ambient temperature, SDR, pipe diameter, coil diameter and compound type. Although both ovality and curvature may reduce naturally with time, special equipment is available to facilitate handling and jointing. Coiled pipe is usually limited to a maximum of DN 125.

Document coil handling and processing requirements using suitable coil handling and levelling equipment to reduce ovality and curvature to an acceptable level to achieve construction tolerances (Refer to 24 TOLERANCES ON AS-CONSTRUCTED WORK).

Validate documented procedures by undertaking a trial installation to demonstrate that coiled pipe can be installed to meet construction tolerances (Refer to 24 TOLERANCES ON AS-CONSTRUCTED WORK).

> Additional information on storage, transport and handling of coiled PE pipes may be found in PIPA Guideline POP 005. In particular, attention is drawn to the dangers associated with stored energy in coiled pipes or those rolled on drums.

Amended the heading of Clause 13.13 and replaced existing text with the following:

13.13 EXCAVATION AND PIPELAYING USING TRENCHLESS TECHNIQUES

Excavation using trenchless techniques differs significantly from typical open trench excavations due to the difficulty of determining accurate geological properties and the potential variability of these properties along the route.

Trenchless excavation may include tunnelling, horizontal boring, directional drilling and/or micro-tunnelling.

Tunnel design is based on less reliable material property assumptions than typical trenching operations.

Before submitting a trenchless excavation proposal for approval to the Superintendent engage an appropriately qualified design consultant to:

(a) review existing geological information;

(b) undertake a site investigation to confirm the existing information and as necessary obtain more specific local geological information; and

(c) prepare Design Drawings and a trenchless excavation specification which, inter alia, should specify the geological conditions assumed in the design, including relevant issues.

Upon approval of a trenchless installation:

(i) implement an inspection plan to compare the actual geological conditions as the excavation progresses with the assumed conditions; and

(ii) implement procedures to assess the implications of any changes in conditions and reassess the adequacy of the trenchless excavation design and ground support before the changes become a risk to health and safety. This may include ceasing relevant work while the reassessment is being conducted.

15.1 INSTALLATION OF PIPES

Change heading of Clause 15.1 as follows:

15.1 INSTALLATION OF PIPES IN TRENCHES

15.1.1 General

Inserted the following two paragraphs after the last paragraph.

At the end of each day’s laying, seal the end of the pipe to prevent ingress of trench material and/or water and other foreign matter.

Undertake welding of pipes in accordance with 15.20 WELDING OF STEEL PIPELINES or 15.21 WELDING OF PE PIPELINES .

15.1.3 Cleaning, inspection and joint preparation

Replace all text with the following:

Inspect all items just prior to use in accordance with 12.2 DELIVERY INSPECTION OF PRODUCTS AND MATERIALS. Remove damaged items from the Works site and replace.

Clean and examine all pipeline system items before installation. Inspect each joint seal for fit and flaws before making the joint in accordance with the manufacturer's instructions.

The jointing methods will vary depending upon the material used and the jointing systems available. The Product and Material Information and Guidance, supplier's drawings and Standard Drawings provide information on jointing systems.

Insert new Clause 15.1.3.1

15.1.3.1 Socket and spigot with elastomeric seals joints

Inspect each joint seal for fit and flaws before making the joint in accordance with the manufacturer's instructions.

Do not use damaged, or incorrect seals.

Treat cut pipe ends in accordance with pipe manufacturer's recommendations.

Chamfer, if required, and provide witness marks on the unmarked length of any cut pipes. Do not score pipes when providing the witness mark.

Ensure the seals, spigot and socket are clean and the correct joint lubricant is used for elastomeric seals.

The above steps apply to pipes formed with sockets or in the form of double socket couplings used to joint plain end pipes. For GRP pipes, a double-socket coupling is usually supplied mounted on one end of the pipe.

Insert new Clause 15.1.3.2

15.1.3.2 Butt Fusion and Electrofusion Welding

For fusion jointing of polyethylene pipes and fittings prepare the jointing surfaces and the geometry of the assembly in accordance with Clauses 15.21 WELDING OF PE PIPELINES

Do not use electrofusion fittings that have been removed from their packaging or have damaged packaging.

> PIPA Industry Guideline POP001 Electrofusion Jointing of PE Pipe and Fittings for Pressure Applications may be used for guidance for non-pressure applications.
>
> PIPA Industry Guideline POP003 Butt Fusion Jointing of PE Pipes and Fittings – Recommended Parameters may be used for guidance for non-pressure applications.

15.1.4 Coiled Plastics pipes

De-coil and treat plastics pipes in accordance with coil handling and processing procedures previously documented and validated (Refer to 12.3.5 Coiled plastics pipe).

Insertion of new Note

Additional information on storage, transport and handling of coiled PE pipes may be found in PIPA Guideline POP 005. In particular, attention is drawn to the dangers associated with stored energy in coiled pipes or those rolled on drums

.

15.1.4 Laying

Changed clause 15.1.4 Laying to clause 15.1.5. Positioning of the pipeline

15.1.5 Positioning of the pipeline

Position pipes in the trench such that the embedment material can be placed and compacted, as required.

Excavate pockets for sockets, couplings, flanges or other projections so as to ensure the pipeline is fully supported along the full length of pipe barrels. Ensure such pockets are the minimum necessary to keep the projection clear of the bedding material, except where access for joint treatment requires additional excavation.

Adjust the pipe to the correct alignment by re-lifting the pipe without affecting the integrity of the joint.

Where pipes are joined in the trench, to prevent movement, restrain pipes already laid before the next joint is made.

Prevent flotation of pipes during laying in accordance with 15.6 FLOTATION CONTROL.

Lay all pipes with their identification markings facing upwards .

Lay the water main on continuously rising grades from scour valve to local high point, notwithstanding any minor irregularities in the ground surface. Make gradual changes in alignment or grade by deflecting at flexible joints after the joints have been made. Comply with the manufacturer's recommendations in respect of maximum deflection for each joint.

15.1.6 Laying and joining pipes and fittings with elastomeric seals

Complete cleaning, inspection and joint preparation in accordance with 15.1.3.1 SOCKET AND SPIGOT WITH ELASTOMERIC SEAL JOINTS

When joining pipes and fittings with elastomeric seal joints:

(a) Ensure that the inside of the socket is clean.

(b) Where elastomeric seals are required to be fitted, clean and fit the seal if not already fitted. Check that the elastomeric seal sits evenly in the socket.

(c) Apply the manufacturer's specified lubricant to the end of the spigot and chamfer of the pipe spigot.

(d) Align the pipes so that there is no deflection at the joints before inserting the spigot in the socket and pushing it home to the witness mark.

(e) Hold the socket end firmly during jointing to prevent previously assembled joints from moving.

(f) Do not insert a metal spigot (e.g. of a fitting) into the socket of a plastics pipe.

(g) Where pipes are required to be cut in the field:

(i). Check the pipe spigot diameter to ensure it is within tolerance.

(ii). Cut the spigot end square and remove all burrs.

(iii). Chamfer the cut end of the pipe with a taper of approximately 15◦ to approximately half the wall thickness, or as otherwise specified by the pipe manufacturer.

(iv). Witness mark the pipe at the distance specified by the manufacturer and make the joint as specified in (a) to (f).

(v). If the same manufacturer does not make spigots and sockets, refer to the socket manufacturer for the correct witness marking depth.

(h) Push the spigot end of the pipe into the socket of the other pipe, not the other way.

(i) Small diameter pipes can be pushed with a log bar. For larger diameter pipes, use of other equipment like a rack, lever puller or excavator as necessary.

(j) Insert the spigot end into the socket till the socket face is positioned at the witness mark.

(k) Jointing of push on fittings is recommended to be done using rack and lever equipment. Jointing of fittings with the pipe can also be done using a suitable tackle e.g. winch method.

(l) After the joint has been made, check the joint to determine if the seal has been correctly inserted.

(m) Inspect the joint to ensure the manufacturers specified insertion depth has been achieved. Inspect the joint by inserting a metal rule into the socket gap and measure insertion depth . Ensure the manufacturers specification has been met and this depth is uniform around the whole circumference. If a difference outside the specified tolerance is found, dismantle and re-join.

> If the joint is to be made using a cut pipe length the pipe spigot diameter must first be checked to ensure it is within tolerance.
>
> For some pipeline systems it's important to select an adjustment pipe (suitably marked according to the applicable standard) for cutting as it will meet the required spigot tolerance for the jointing proposed, without any machining required

Insert new Clause 15.1.7

15.1.7 Laying and jointing of polyethylene pipes and fittings

Undertake inspection and joint preparation in accordance with 15.1.3.2 BUTT FUSION AND ELECTROFUSION WELDING

When fusion jointing of polyethylene pipes and fittings refer to PIPA POP001 and POP003.

Pipes may be jointed at ground level and then lowered into position.

Installation shall allow for thermal contraction and expansion of the PE pipe in accordance with AS/NZS 2033. The allowance shall be sufficient for a temperature change of at least 35°C.

PE pipes shall be laid in the trench to line and level with full embedment and partial trench backfill without restricting the ends until the pipe has had time to stabilise to ground temperature.

Where manual cold bending of the PE pipe has been employed, the combined effect of pipe bending and thermal contraction shall be considered to ensure that strain in the pipe wall remains acceptable.

Undertake welding of pipes in accordance with 15.21 WELDING OF STEEL PIPELINES or 15.22 WELDING OF PE PIPELINES.

For trenchless installation of pipes, install in accordance with the Specification and relevant Design Drawings.

15.1.8 Lift and re-lay construction

Change 15.1.5 Lift and re-lay construction to Change 15.1.8 Lift and re-lay construction

15.1.8 Lift and re-lay construction

If lift and re-lay construction is specified:

(a) Where specified by the Water Agency, supply affected properties with a temporary water service. The temporary supply to each property shall incorporate a ball valve so the property can be isolated without disrupting water supply to other properties supplied from this temporary water supply;
(b) Swab mains in accordance with 18 Swabbings and
(c) Check each individual service for water availability prior to vacating the site each day.

15.8 TAPPING OF MAINS, PROPERTY SERVICES AND WATER METERS

Replaced sixth paragraph with the following:

Where tapping is specified for PE mains use either an authorised electrofusion tapping saddle complying with WSA PS–329 or an authorised mechanical tapping saddle complying with WSA PS–310.

15.21 Welding of PE Pipelines

Replace the entire content in Clause 15.21 with the following

15.21.1 General

Use electrofusion or butt fusion for joining pipe-to-pipe or fitting-to-pipe.

Undertake all welding in accordance with the Specification, relevant Design Drawings and approved jointing procedures as specified in Clause 15.21.2 and 15.21.3

Butt fusion and Electrofusion shall be performed by competent persons having current certification and experience as defined in Clause 15.21.6.

15.21.2 PE Butt Fusion Welding

Butt-fusion jointing procedures shall be in accordance with ISO 21307.

Other fusion procedures may be used subject to approval by the Water Agency.

PIPA Industry Guideline POP003, should be used for guidance on the butt fusion jointing of PE pipe and fittings.

All equipment for butt fusion jointing shall comply with the requirements of ISO 12176-1.

Butt fusion parameters shall be validated by test before welding commences on site.

15.21.3 PE Electrofusion Welding

Electrofusion jointing procedures shall be carried out in accordance with the manufacturer’s instructions for each specific size and type of fitting.

Electrofusion control boxes shall comply with ISO 12176-2.

PIPA Industry Guideline POP001, should be used for guidance on the electrofusion jointing of PE pipe and fittings for pressure applications.

Electrofusion joints shall be validated by test before welding commences on site – see clause 15.21.4.2 Electrofusion – Pre-Construction test welds

15.21.4 Weld Testing Butt Fusion and Electrofusion Joints

Joining pipes and fittings by electrofusion or butt fusion shall be to an approved jointing procedure that has been qualified by destructive testing in accordance with ISO 13953 and ISO 13954.

Fusion joining procedures shall be qualified prior to the commencement of welding on site.

15.21.4.1 Butt Fusion – Pre-Construction Test Welds

Before production jointing commences qualification of the butt fusion procedure shall be carried out unless a suitable pre-qualified procedure has been approved by the Water

Agency. Qualification establishes the optimum weld procedure for the project within the scope of the ranges for each individual parameter nominated in ISO 21307.

Qualification welds shall optimise the weld parameters and be tested in accordance with ISO 13953 *Polyethylene (PE) pipes and fittings – Determination of the tensile strength and failure mode of test pieces from a butt-fused joint*

Qualified Procedures may be grouped by diameter to reduce the amount of qualification testing. The recommended groupings are shown in Table 15.1 below

Table 15.1: Butt Fusion testing qualification requirements

Procedure Qualification Test Pipe Diameter and for each SDR	**Qualifies for sizes**
Any ≤DN225	≤DN225
Any >DN225 – DN450	DN225 -DN450
>DN450	Each pipe diameter shall be tested

A pilot weld shall be undertaken for each welder, welding machine, pipe diameter and wall thickness using the qualified procedure.

A record of the parameter values for each weld shall be made.

Each pilot weld shall be performed on the actual pipe used in the project and under site conditions.

Pilot welds shall be tested in accordance with ISO 13953.

Options to assist in the interpretation and assessment of butt fusion tensile tests can be found in PIPA document POP014.

Only when these pre-construction joints pass the acceptance criteria shall the project proceed.

Test samples shall be identified by

pipe size,

(a) SDR,
(b) PE material composition grade,
(c) date,
(d) actual weld parameters used
(e) welder number, machine and welding conditions at the time of welding.

Butt fusion joint samples shall be submitted for destructive testing to an approved NATA registered testing laboratory.

A field welding QA plan shall be submitted, and approved, before welding commences. REFER TO CLAUSE 15.21.5 QUALITY PLAN

15.21.4.2 Electrofusion – Pre-Construction test welds

Before production jointing commences qualification of the electrofusion procedure shall be carried out.

Qualified electrofusion joints may be grouped by diameter to reduce the amount of qualification testing. The recommended groupings are shown in Table 15.2 below

Table 15.2; Electrofusion socket and saddle joint testing qualification requirements

Procedure Qualification Test Pipe Diameter and each fitting brand	Qualifies for sizes
Any ≤DN225	≤DN225
>DN225	Each pipe diameter shall be tested

Test joints shall be cut such that there is a minimum of 300 mm of pipe protruding either side of the joint.

Test samples shall be identified by

(a) pipe size,
(b) SDR,
(c) PE material composition grade,
(d) date,
(e) type and brand of fitting
(f) welder number, machine and welding conditions at the time of welding.

Electrofusion joint samples shall be submitted to an approved NATA registered testing laboratory.

Electrofusion joints shall be tested using the peel decohesion test in accordance with the requirements of ISO 13954.

When tested, electrofusion joints shall meet the requirements of AS/NZS 4129 Clause 3.5 Mechanical characteristics.

Only when these pre-construction joints pass the acceptance criteria shall the project proceed.

15.21.5 Quality plans

A field welding quality plan shall be submitted, and approved, before welding commences.

A quality plan shall be prepared to demonstrate

(a) Safe Work Method statements and Job Safety Analysis
(b) Thermoplastic Welder Personnel Training and Qualifications
(c) Equipment details, brand, model, maintenance, servicing, and calibration of equipment
(d) Welding and joining procedures / including a record of all weld parameters.
(e) Test Sampling Plan for the number of test welds to be undertaken during the construction phase.

(f) Pre-construction test welds using inputs from items (b), (c) and (d)
(g) inspection and test records.

It is also recommended that quality records for each weld, numbered and located on a plan of works, be retained for at least 6 years from the date of installation.

15.21.5.1 Butt fusion – Test Sampling Plan during construction

Before construction commences qualification and pilot welds shall meet the test criteria - refer to Clause 15.24.4.1.

Once construction commences two types of testing shall be applied:

(a) Visual inspection of each joint
(b) Destructive testing of a selected joint. The Water Agency shall nominate the specific joint that will be destructively tested.

15.21.5.1.1 Visual inspection

All butt fusion joints shall be visually inspected around the full circumference.

All butt fusion joints shall be assessed in accordance with Table 1 and Table 2 of PIPA document POP 014. Joints that fail the acceptance criteria shall be reported, the parameters and welding process shall be investigated and corrective action taken. The Water Agency may require the joint be cut out.

All butt fusion joint external weld beads shall be removed using a suitable bead removal tool and then tested in accordance with POP014. If the bead separates, the parameters and welding process shall be investigated, reported and corrective action taken. The Water Agency may require the joint be cut out..

16.21.5.1.2 Destructive testing

Samples for destructive testing of butt fusion joints shall be provided for each individual pipe size and standard dimension ratio (SDR) as follows:

(a) 1 joint in the first 10 joints
(b) 1 joint in every 20 joints (or part thereof) for the remainder of the pipeline after the testing of the first joint as prescribed above meets the testing requirements.

> Note: Following a series of successful joint tests the test frequency maybe further reduced with the approval of the Water Agency based on consistent successful welder performance. For example the test frequency could be reduced to 1 joint in every 50 joints (or part thereof) for the remainder of the pipeline.

Where testing reveals nonconformance to the test requirements the joint shall be reported, investigated and any corrective action recommended. In addition the previous weld to the failed test weld shall be cut out and tested. If the second weld also fails to meet the test criteria the project shall be stopped. Testing shall continue until the Contractor can demonstrate the welds meet the testing requirements.

15.21.5.2 Electrofusion – Test Sampling Plan during construction

Production Electrofusion jointing shall only commence following successful testing of the qualification weld.

Once construction commences two types of testing shall be applied:

(a) Visual inspection of each joint
(b) Destructive testing of a selected joint. The Water Agency shall nominate the specific joint that will be destructively tested.

15.21.5.2.1 Visual inspection

All electrofusion joints shall be visually inspected in accordance with the acceptance criteria of Table 4 of POP 014. Joints that fail the acceptance criteria shall be reported, investigated and any corrective action recommended and if required by the Water Agency shall be cut out and replaced with new fittings.

Electrofusion couplings and saddles that indicate error readings, short circuiting, exposed wires, failure of coupling melt indicators and or melt outside the weld zone shall be cut out and replaced with new fittings.

15.21.5.2.2 Destructive testing

Samples for destructive testing of electrofusion joints shall be provided for each individual pipe size as follows:

(a) 1 joint in the first 10 joints
(b) 1 joint in every 20 electrofusion joints (or part thereof) for the remainder of the pipeline after the testing of the first joint as prescribed above meets the testing requirements.

Note: Following a series of successful joint tests the test frequency maybe further reduced with the approval of the Water Agency based on consistent successful welder performance. For example the test frequency could be reduced to 1 joint in every 50 joints (or part thereof) for the remainder of the pipeline.

Where testing reveals nonconformance to the test requirements the joint shall be reported, investigated and any corrective action recommended. In addition the previous weld to the failed test weld shall be cut out and tested. If the second weld also fails to meet the test criteria the project shall be stopped. Testing shall continue until the Contractor can demonstrate the welds meet the testing requirements.

15.21.6 Welder qualifications

All welders shall have successfully undertaken the following Units of Competence of the Plastics, Rubber and/or Cablemaking Training Package PMB07 appropriate to the welding processes used:

(a) PMBWELD301E - Butt weld polyethylene plastic pipelines
(b) PMBWELD302E - Join polyethylene plastic pipelines using electrofusion welding

Training shall be provided by Registered Training Organisations (RTO's) that are accredited by State/Territory Training Authorities under the Australian National Training Authority (ANTA) guidelines and conforming to PMB 07 Competency Standards prepared by Manufacturing Learning Australia, Qualification Framework for the plastics, rubber and cable making industry.

RTOs listed on the PIPA website (https://pipa.com.au/welder-training/) are preferred as they also commit to deliver a detailed course curriculum.

The RTO's providing training in all forms of welding plastics pipeline systems shall have staff qualified in presenting courses that meet competency standards covered by PMBWELD301E and PMBWELD302E.

"Successfully undertaken" shall mean "Statement of Attainment" for all those appropriate Units of Competence.

Only personnel who have successfully completed the above training programs shall be permitted to butt fuse or electrofuse PE systems .

Certification shall be valid for 2 years. At the end of this period, renewal of the certification shall be required.

Certified welders shall demonstrate continuous welding activity and any break of more than six months shall require renewal of certification.

Certification details shall be carried by field personnel on-site, and be made available as required.

In addition to having current certification welders shall be initially restricted to welding pipes and fittings in sizes <DN225 until they can demonstrate either a successful track record of welding within this size range or that they have undertaken specific training on larger size pipe.

Welders demonstrating a successful track record of welding in sizes up to DN225 shall be permitted to weld pipelines up to DN450. Similarly, welders shall demonstrate a successful track record of welding up to DN450 before being permitted to weld pipes and fittings >DN450.

Inserted New Clause 15.22

15.22 Connections to pipes of other materials

Make connections to PVC/ABS/DI/steel/GRP pipelines using PE flange adaptors and backing rings with AS/NZS 4087 Figure B2 mating dimensions.

16.6 CONCRETE EMBEDMENT AND ENCASEMENT

Insert new second and third paragraph.

Where a pipe is set in concrete and damage to pipe surfaces could occur as a result of movement of the pipe relative to its surrounding, a membrane shall surround the pipe and fittings to permit movement without scoring.

Protection may be by wrapping in a compressible membrane with a minimum of 2-3 mm made polyethylene, PVC , geotextile fabric or felt.

APPENDIX F GUIDELINES FOR WATER MAINS IN SLIP AND POTENTIALLY UNSTABLE AREAS

F5.4 ALTERNATIVE CONSTRUCTION TECHNIQUES

Added cross-reference to Clause 5.5 at the end of the paragraph.

> It may be possible to use trenchless techniques (directional drilling or microtunnelling) to go around or under potentially unstable areas, subject to geotechnical assessment and addressing the impact on drainage and capabilities of the method proposed for a particular project. (Refer to 5.5 TRENCHLESS TECHNOLOGY)

Inserted New Appendix L

APPENDIX L TRENCHLESS TECHNOLOGIES

L1 GENERAL

There are currently several technologies that are suitable for the construction of borehole and small scale tunnelling works. A general description of each technique is detailed in this Appendix and a summary of performance characteristics and constraints is listed in Table L.1.

L2 HORIZONTAL DIRECTIONAL DRILLING (HDD)

This technology involves the drilling of a small diameter pilot hole along a predetermined alignment by means of a drill head and drill rods thrust from a drilling rig. The pilot hole is enlarged by a process called reaming to construct a borehole of sufficient size to accommodate the product pipe (liner pipe). The installation is carried out by pulling or pushing the product pipe into the borehole. Soft ground material may require prior installation of a casing pipe to support the bore, or the pipe is installed immediately behind the reaming equipment as the hole is enlarged.

Guidance of the drilling equipment is undertaken by determining the orientation and location of the drill bit via a system that transmits from the drill head or via a surface tracking system. Steering is achieved by rotation of the drill head to suit the direction to be drilled. In this way, both horizontal and vertical curved profiles can be drilled.

Drilling, reaming and pipe installation is generally carried out using a drilling fluid (drilling mud), generally bentonite. The drilling mud acts as a lubricant and a method of returning drilling cuttings to the surface for treatment. The drilling mud also aids in supporting the borehole during drilling, reaming and pipe installation in collapsible strata.

The general limit on drilling very flat grades is not so much due to actual equipment limitations, but is more so due to the inherent characteristics of steering control or problems of deflection of the drill head in varying ground conditions. These drilling "errors" may compound over the greater the distance drilled. The implication is the risk of reverse grade or ponding locations, that may be unacceptable on flat-graded gravity systems.

HDD machines are divided into three distinct categories based on size, power and performance. Mini-HDD rigs are typically used for the installation of small diameter pipes or conduits, at shallow depths for relatively short lengths, in soft soil conditions and where grade accuracy of the installed pipe is not a significant issue. Guidance control is generally via a manual operated system.

Midi-HDD rigs are used typically in the mid range distances, for medium sized diameter installations. Installations in rock or soil are readily achievable and guidance and grade control conducted by sophisticated "down-hole" surveying equipment and techniques.

Maxi-HDD rigs are typically utilised for long distance, large diameter installations where the higher performance power characteristics are required for drilling in hard rock and for installation of longer distance pipelines. Sophisticated "down-hole" surveying equipment and techniques are utilised.

This system is generally not specified for the construction of sewers due to the tolerances that can be achieved using this technique. If this technique is to be used, it is important to allow significant extra grade to allow for the large construction tolerances in this technique.

L3 MICRO-TUNNELLING

This technique generally involves a hole being bored by the cutting heads and boring equipment being thrust along a straight alignment from a launching shaft to a receiving shaft by means of rods or jacks.

Micro-tunnelling can be carried out by several different processes depending on the strata to be bored through. Processes allow for boring through solid rock, soft material and water-charged ground and the methods used will be dependent on the material, the size of the product pipe and the Contractor's equipment.

Technologies exist that allow a pressure balance against earth and groundwater pressures when boring in water-charged, collapsible strata.

The product pipe is generally installed after completion of the bore (in self-supporting strata) or jacked immediately behind the boring equipment (or installed within casing pipe) in collapsible material.

Guidance of the boring equipment is by laser and survey equipment which allows for the boring of very flat grades with great accuracy. Steering is accomplished by varying thrust on the jacks or boring rods.

Micro-tunnelling is carried out using drilling fluids, generally water for boring in rock or bentonite slurry in soft materials. Cuttings are removed from the borehole by vacuum extraction or via a slurry system to the surface for treatment.

It should be noted that the limit on boring distance is dependent on the size of the machine (power via jacking system), the diameter hole being bored, the limit of accuracy of the guidance system (i.e. the distance that the laser loses accuracy) and the strata being bored through.

L4 UNGUIDED BORING/THRUST BORING/AUGER BORING

These techniques are generally used for pipeline crossings of major roads and railways in situations where grade is not a critical factor.

Typically, a range of auger boring and cutting head arrangements driven by thrusting or jacking from a launch pit to a receiving pit are utilised.

Bores can be constructed to accommodate a wide range of pipe sizes, which can be installed within casing pipe or jacked directly into the bore, dependent on ground conditions.

Boring fluids are generally not used however this is dependent on the technique and the ground conditions.

The limits on accuracy associated with unguided methods is generally appropriate for the relatively short distances required for infrastructure crossings.

L5 PIPE JACKING

This technique involves a tunnel being excavated by cutters located at the face of a shield (cylindrical body) which is thrust along an alignment from a launching shaft to a receiving shaft by means of jacks. The pipe lengths are simultaneously installed (jacked) directly behind the shield.

Excavated material is generally removed via a conveyor system from the cutting face back to the launch shaft.

Grade and directional control is by laser guidance systems.

Pipe jacking can be carried out typically in any strata other than rock, however water- charged conditions generally require ground treatment methods to manage water levels.

An item of note is that this technology allows installation of conduits in traversable sizes and can incorporate personnel actually working behind the cutting face to control the machine or actually physically excavating and removing material by manual means.

L6 MINI-TUNNELLING

Mini-tunnelling utilises similar principles to micro-tunnelling to construct large diameter (traversable) boreholes or tunnels.

Tunnelling can be carried out in hard strata using "free" boring methods that allows installation of a tunnel liner or product pipe after completion of the tunnel.

Tunnelling in soft, water-charged material can be undertaken by machines that utilise a pressure balance system to resist earth and groundwater forces. The tunnel liner or product pipe is generally jacked directly behind the machine.

Guidance of the equipment is by laser and computer systems which allows accurate tunnelling at very flat grades and allows drives greater than that of micro-tunnelling. The use of inter-jack stations also allows additional drive lengths. However, the drive lengths of these techniques can still be effected by the effects of the intensity of the laser under various atmospheric conditions i.e. dust, temperature, light

Steering is accomplished by varying thrust on the jacks or rods or from thrust mechanisms on the sides of the tunnelling machines. This latter technique also allows for greater drive lengths.

The technology now exists to tunnel and line with segmental components simultaneously. In addition, the technique can be carried out so that the tunnelling machine thrusts off each incremental section of liner or previously pipe installed, which in effect allows a continuous drive to be undertaken.

TABLE L1 GENERAL PERFORMANCE CHARACTERISTICS OF BOREHOLE AND TUNNELLING TECHNOLOGIES

Technology	Diameter (m)[1]	Length (m)	Depth (m)	Grade (%)	Accuracy[2]	Strata	Application
Horizontal Directional Drilling	100 – 1100[3] Up to 1200[4]	Up to 1200[3] 1000 – 2000[4] Up to 10,000[5]	N/A	≥1.5[6] ≥2.5-3.0[7]	±200 mm/1000 m ±20 mm at any point	Hard rock, clays, shales, sands, silts, water-charged strata	Near-horizontal bores, inclined bores, directional (curved) bores, waterway and infrastructure crossings for gravity and pressure pipelines
Micro-tunnelling	150 – 900 Up to 1200	Up to 150m Up to 250m[8]	Limited only by cost, safety, material extraction[9]	0.1–1.0 1.0-10.0 10.0-50.0	±10 mm/100 m ±40 mm/200 m ±5 mm at any point	Hard rock, clays, shales, sands, silts, water-charged strata	Horizontal bores, near horizontal bores, infrastructure crossings for gravity or pressure pipelines. Changes in directions accommodated at shafts[10]
Boring	100-500 Up to 1200	20-30 Up to 50	Generally for shallow depths	Generally not for specified grade	Dependent on ground conditions, operator skill	Clays, shales, sands, silts, water-charged strata	Near horizontal bores for infrastructure crossings for pressure (and sometimes gravity) pipelines.
Pipe jacking	1200 – 3000+	Up to 50 Up to 1000[11]	Limited only by cost, safety, material extraction	Generally 0.1– 5.0 range	±20 mm/100 m ±5 mm at any point	Softer rock, clays, shales, sands, silts, some water-charged strata	Near horizontal bores for infrastructure crossings for pressure and gravity pipelines. Being used for long distance gravity pipelines overseas. Changes in directions accommodated at shafts[10]
Mini-tunnelling	≥1200 mm	Generally 100 m-500 m but theoretically unlimited[12]	Limited only by cost, safety, material extraction	0.1-10 Up to 50	±20 mm/100 m ±10-15 mm at any point	Hard rock, clays, shales, sands, silts, water-charged strata	Being used for long distance gravity (generally) conduits. Changes in directions accommodated at shafts[10]

1 Diameter = product pipe to be installed for HDD, micro-tunnelling, boring, pipe-jacking. Diameter = tunnel for mini-tunnelling.

2 Approximate only – dependent on guidance system used, site conditions, length.
3 Carried out to date in Australia.
4 Carried out overseas.
5 Carried out in oil field drilling.
6 General limit.
7 Suggested minimum grade limit for significant length gravity wastewater boreholes.
8 Dependent on ground conditions.
9 Typical depth 10 – 15 m.
10 Some horizontal curve alignments currently being carried out overseas.
11 Carried out overseas (requires intermediate jacking points).
12 Limited by logistics, laser limits, jacking forces.